

# Ammonia Emissions in the U.S.: Assessing the role of bi-directional ammonia transport using the Community Multi-scale Air Quality (CMAQ) Model

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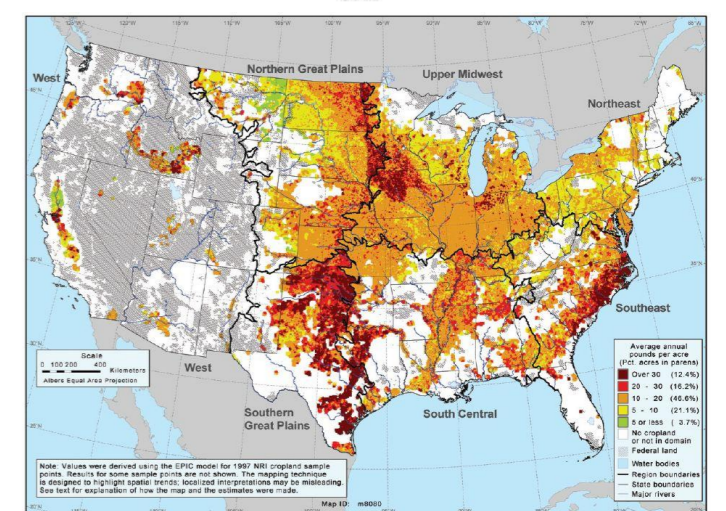
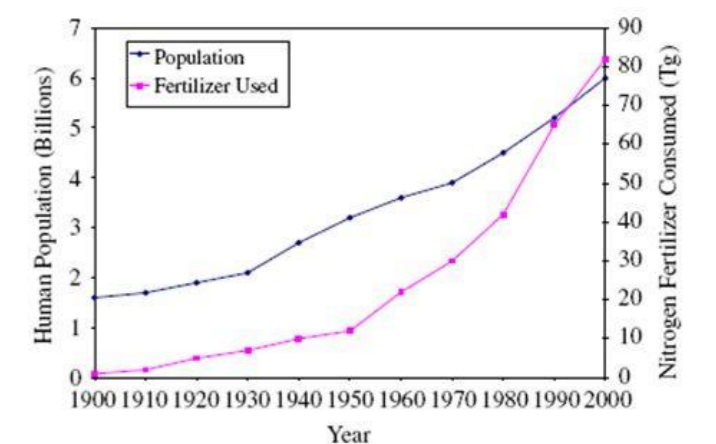
## 1. Introduction

### 1.1 Project Description

A pilot study of bi-directional ammonia ( $\text{NH}_3$ ) flux modeling in CMAQ for the Eastern U.S. is underway. The study develops and tests bi-directional flux algorithms, explores methods of providing agricultural fertilizer information into CMAQ, and clarifies possible  $\text{NH}_3$  and overall one-atmosphere chemical budget changes with the full implementation of the bi-directional flux option planned for the 2011 CMAQ release. One focus area is the adjustment of the current CMAQ bi-directional flux module to include a dynamic soil emission potential component. The soil emission potential is calculated offline using commercial fertilizer application survey data from the National Nutrient Loss & Soil Carbon (NNLSC) Database, with additional crop acreage data obtained from the 2002 U.S. Census of Agriculture and meteorology obtained from MCIP.

### 1.2 Ammonia

- **Impacts**
  - Ecosystems: soil & water acidification, eutrophication, forest damage
  - Atmospheric: neutralization of sulfuric and nitric acid, leading to the formation of fine particulate matter ( $\text{PM}_{2.5}$ )
- **Trends**
  - Not federally regulated – fertilizer sales increasing; ammonia emissions projected to increase
  - Energy Independence and Security Act (EISA-RFS2) – increased bio-fuel production



40-year average of annual per-acre nitrogen volatilization (Potter et al., 2006)

## 2. Methods

### 2.1 Calculating Emission Potential

$$\Gamma_g = \frac{[\text{NH}_4^+]}{[\text{H}^+]}$$

$[\text{NH}_4^+]$  is the ammonium ion concentration in the soil  
 $[\text{H}^+]$  is the hydrogen ion concentration in the soil

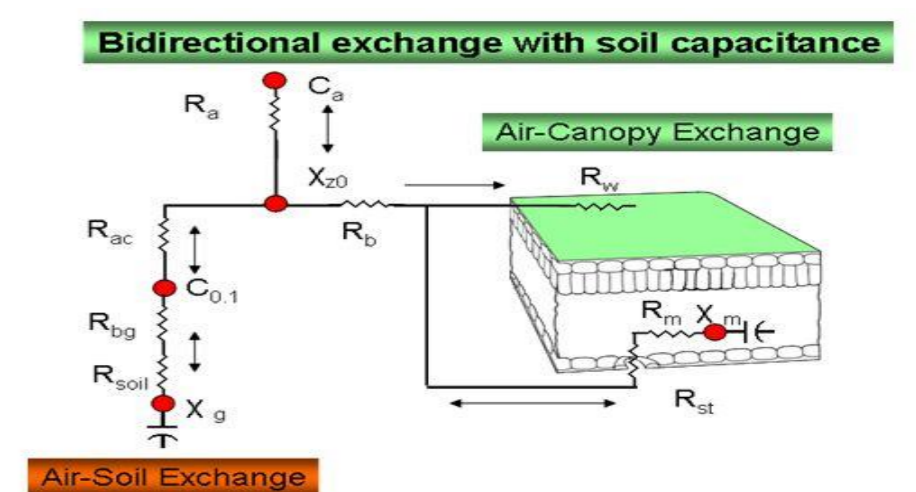
- $\Gamma_g$  calculated via a box model constructed from USDA algorithms representing the nitrification process
- Box model inputs: physical properties of the ambient soil profile, meteorology, and crop management practices

### 2.2 Gamma Implementation in CMAQ

$$X_g = \frac{A}{T_s} \exp^{-B/T_s} \Gamma_g$$

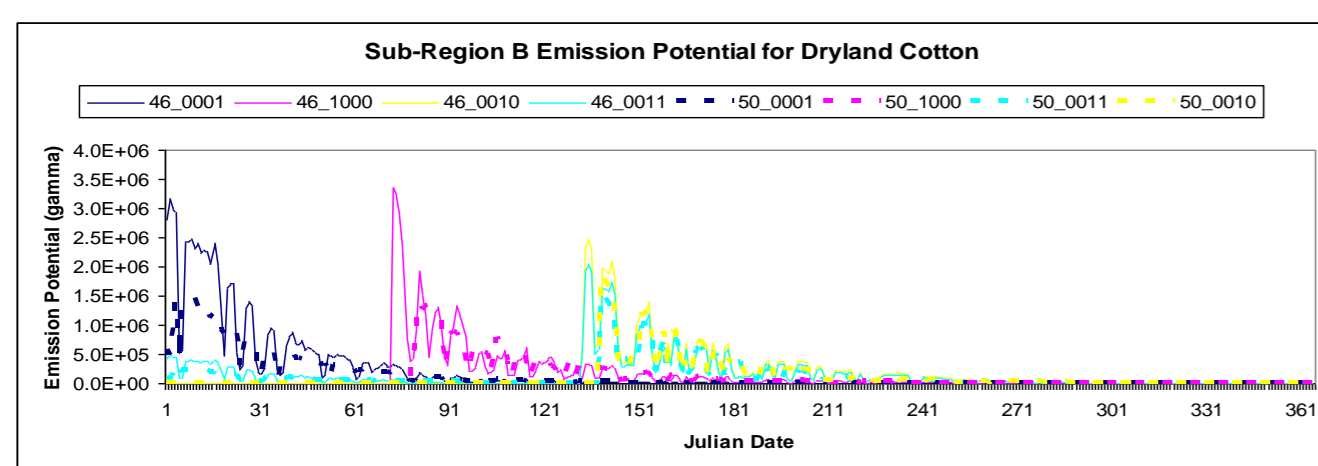
1. Remove NEI fertilizer emissions data and input daily  $\Gamma_g$  per sub-region via IO/API file.
2. If the air concentration at the soil-air interface,  $C_{0,I}$ , is less than  $X_g$ ,  $\text{NH}_3$  will volatilize.
3. Ammonia flux calculated within CMAQ via bi-directional flux module.

$X_g$  is the compensation point-based  $\text{NH}_3$  concentration ( $\text{ng m}^{-3}$ )  
 $A$  and  $B$  are Henry's Law coefficient constants  
 $T_s$  is the soil temperature (K)  
 $\Gamma_g$  is the dimensionless  $\text{NH}_3$  emission potential (gamma)



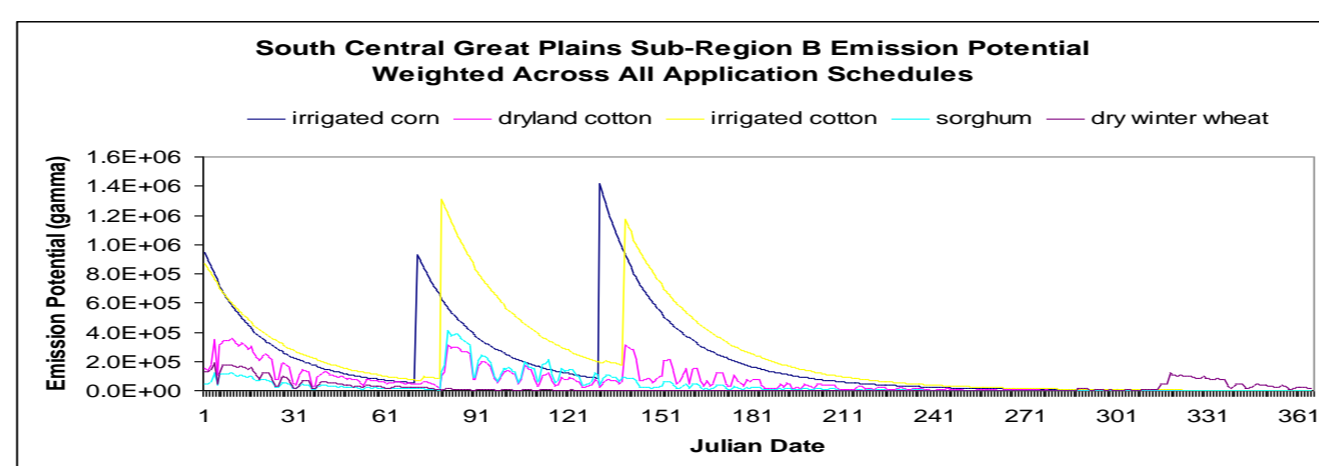
## 3. Results – Soil Emission Potential; example shown for sub-region in Texas, USA

**Step 1:** Identify sub-regions with relatively distinct crop mixes based on the magnitude of nitrogen fertilizer applied in each of five U.S. regions.

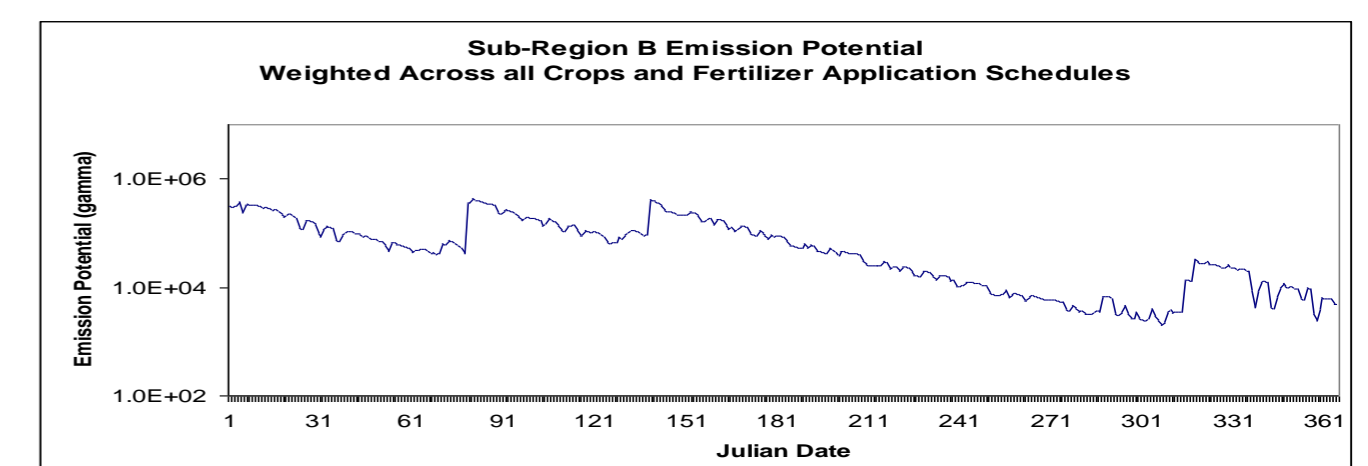


**Step 3:** Compute nitrogen application time profiles by state and calculate  $\Gamma_g$  for each crop and application time scenario.

**Step 2:** Compute a median annual nitrogen application rate for each crop in the sub-region.



**Step 4:** Multiply daily time series of  $\Gamma_g$  for each crop by the fraction of crop acres in each state and by probability of application scenario.



**Step 5:** Multiply each weighted crop  $\Gamma_g$  time series (from step 4) by fraction of crop acres in the sub-region and sum across all crops.

## 4. Current & Future Work

- **CMAQ Modeling with Bi-directional  $\text{NH}_3$  Flux**
  - Full year CMAQ model run over the Eastern U.S. using the 2002 NEI with fertilizer emissions removed and  $\Gamma_g$  input via IO/API file
  - Compare model outputs for emissions, concentration, and deposition to base 2002 model run for  $\text{NH}_3$  and  $\text{PM}_{2.5}$
- **Hypotheses / Expectations**
  - Shifts in magnitude and seasonality of  $\text{NH}_3$  emissions & subsequent atmospheric concentration
  - Increase in wet deposition and decrease in dry deposition

## 5. References

- Cooter, E.J., J.O. Bash, J.T. Walker, M.R. Jones, and W. Robarge, 2009. Estimation of  $\text{NH}_3$  Bi-Directional Flux from Managed Agricultural Soils. *In review*.
- Potter, S.R., Andrews, S., Atwood, J.D., Kellogg, R.L., Lemunyon, J., Norfleet, L., and Oman, D., 2006. Model Simulation of Soil Loss, Nutrient Loss, and Change in Soil Organic Carbon Associated with Crop Production. Natural Resources Conservation Service, U.S. Department of Agriculture, Conservation Effects Assessment Project (CEAP), Government Printing Office, Washington, D.C., p. 235.

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